IMPROVING ENVIRONMENTAL BENEFIT ASSESSMENTS:
APPLICATION STUDIES AND METHODS DEVELOPMENT

STRATOSPHERIC OZONE DEPLETION, SKIN DAMAGE RISKS, AND PROTECTIVE ACTION

by

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Prepared under EPA COOPERATIVE AGREEMENT #CR-814647-01-0
with the Office of Economy and Environment,
U.S. Environmental Protection Agency
Washington, DC 20460

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JANUARY 1999

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ACKNOWLEDGEMENT

Portions of this report are reproduced from

Dickie, Mark and Shelby Gerking, "Formation of Risk Beliefs, Joint Production, and Willingness to Pay to Avoid Skin Cancer," Review of Economics and Statistics, 78 (August 1996), 451-63.

Dickie, Mark and Shelby Gerking, "Genetic Risk Factors and Offsetting Behavior: The Case of Skin Cancer," Journal of Risk and Uncertainty, 15 (October 1997), 81-97

TABLE OF CONTENTS

1. INTRODUCTION

This report contributes to policy making on control of stratospheric ozone depletion. As discussed by Kerr (1988), Shell (1988), and Mintzis (1986), stratospheric ozone depletion poses increased worldwide risks of skin damage (including cancer), cataracts, and immune system suppression in addition to damage to terrestrial ecosystems and certain marine organisms. Moreover, scientists predict continued ozone depletion and thus increased future health and ecosystem problems despite international protocol that limits CFC and halon production. Appropriate regulation of these, or any other, health risks depend on whether people clearly perceive hazards, how perceptions influence protective action, and on the benefits of potential risk reduction.

This report uses a field study of beliefs about skin cancer to provide new evidence on how people view risky situations that may be related to stratospheric ozone depletion. Four contributions are envisioned. First, data are collected that measure risk beliefs held at the time of the data were collected. In some other studies, people are asked to recall beliefs held months or even years earlier (Smith and Johnson 1988, Smith Desvousges, Fisher, and Johnson 1988, Bernknopf, Brookshire, and Thayer 1990) or are told what to believe about risk in a specific hypothetical situation (Viscusi, Magat, and Huber 1987). Second, results presented yield insights into how risk beliefs are formed. Third, reservation prices for a sunscreen product are used to estimate willingness to pay for reduced skin cancer risk. These estimates are based on respondents' indifference together with a new method for treating certain joint production problems (see, for example Pollack and Wachter 1975) that arise in a household production framework. Fourth, the extent of offsetting behavior is investigated as it relates to protective

actions that people may take. For example, do people with greater genetic protection against skin cancer risk tend to take fewer protective actions?

The remainder of the report is organized into eight sections. Scientific evidence concerning links between CFC and halon emissions, and stratospheric ozone depletion, and human health risks are summarized in Section 2. Methods of monetizing benefits of one aspect of health effects, skin damage in humans, are evaluated in Section 3. For a useful discussion of how to value reduced incidence of cataracts due to stratospheric ozone depletion, see Rowe, Neithercut, and Schulze (1987). Section 4, then, describes the data used in the study. These are primary field data collected in two U.S. cities during Summer and Fall, 1988. Section 5 presents empirical evidence on the determinants of risk beliefs. Section 6 presents results on willingness to pay to avoid risk of skin cancer. Section 7 estimates determinants of precautionary actions. Section 8 estimates the extent of offsetting behavior. Section 9 concludes.

2. STRATOSPHERIC OZONE DEPLETION AND HUMAN HELATH RISKS

CFCs and halons are used worldwide in a broad range of applications including foam insulation, air conditioning systems, fast food containers, solvents for cleaning metallics, and in some countries, as an aerosol propellant. Most of these chemicals eventually end up in the atmosphere either through direct injection, leakage from air conditioning systems, evaporation from solutions, or burning of solids. The emission process can take up to 20-30 years and is highly variable in length depending on the application. As first observed by Molina and Rowland (1974), once in the atmosphere these inert gases have a lifetime of 40-150 years and tend to migrate slowly to the stratosphere. These authors predicted that if CFC production continued at

1974 rates, stratospheric concentrations of these gases could reach 10-30 times mid 1970s levels before the end of this century. This increased volume of CFCs could deplete the stratospheric ozone layer, leaving earth more vulnerable to a variety of damages from ultraviolet radiation exposure.

Initial concern in the 1970s focused on two types of chlorofluoromethanes, CCl_3F (CFC-11) and CCl_2F_2 (CFC-12), because these were the only compounds in major production. More recent research, however, has provided detailed evidence of the presence of more than ten compounds in the upper atmosphere which pose a threat to the Earth's ozone layer. Of these compounds, CCl_2FCClF_2 (CFC-113), Halon 1301, and Halon 1211 have come into use in the cleaning of metallics and in fire extinguishing systems, and have quadrupled in atmospheric concentration in the past nine years. Methylchloroform (a degreasing agent), and CFC-22 (home air conditioner refrigerant) are also found in greater abundance. These chemicals are not readily affected by the natural processes that cleanse the atmosphere of pollutants, such as dissolution in raindrops, breakdown by sunlight, or reaction with oxidants in the lower atmosphere.

Once in the stratosphere, these inert compounds can be broken down by solar radiation into various constituents, including carbon, chlorine and fluorine. Chlorine reacts with ozone to produce chlorine monoxide and oxygen. Chlorine monoxide, in turn, can react with free oxygen, releasing chlorine atoms as a by-product. Consequently, the chlorine atoms are once again free to repeat the reaction process (perhaps 100,000 times) before they eventually drift down from the stratosphere. The worldwide release of approximately one million tons of CFCs per year combined with a potential multiplier effect of 100,000 explains why these chemicals can have such destructive power.

Experimental data from ground based stations show clear evidence of the presence of chlorine in the upper atmosphere. With chlorine in or around the ozone layer, chemical attack on ozone must occur. Estimates show that ozone depletion takes place at altitudes of around 25 miles, and that eventual losses of approximately 50 percent of the earth's total column ozone concentration will ensue if chlorfluorocarbon and halon release is continued at 1987 rates (Rowland, 1987).

An important question as to the extent of stratospheric ozone damage has been addressed with recent observational evidence. Measurements taken at Halley Bay, Antarctica have confirmed that greater than 40 percent of the total column ozone concentration above the continent dissipates in the spring period. Most of this decrease has occurred since the 1970s. Other instruments such as the satellite based Nimbus 7 Total Ozone Monitoring System, and Ultra Violet System have verified the growth of the ozone hole over the Antarctic since 1979. Satellite data also reveals decreases which are not confined to just the area over the South Pole, but extending as far out as 45 degrees south (Solomon, 1987).

Similar changes in ozone concentrations have been observed on a global scale. Satellite data spanning the eight year period from November 1978 through October 1986 show that total global ozone is decreasing in the northern regions as well as central and equatorial sections (Heath, 1987 and Angell, 1987). These studies reported substantial decreases in total global ozone occurring after 1981. Significant decreases were observed at the north pole and at mid-latitudes during the 1982-83 winter following the eruptions of El Chichon, but even larger decreases in global ozone occurred at mid-latitudes in the northern hemisphere during the winter of 1984-85. Northern hemisphere ozone has since followed a continuing downward trend

showing little evidence of recovery. The combined data indicates that total column ozone worldwide has decreased by 4.4 percent from 1978-1986.

Continued decline in earth's ozone shield has implications for skin damage risks. These risks are exacerbated because western societies have acquired the attitude that a sun-tanned or bronzed look is healthy and attractive. As sun seeking behavior became more widespread, unfavorable effects of prolonged exposure ranging from accelerated skin wrinkling to skin cancer became more prevalent. People with white skin can be exposed to mid-latitude, summer sunlight for approximately 15 to 20 minutes and develop a mild sunburn. Careful, repeated exposure to small doses will produce a protective tan in about two thirds of the white population, but the remaining one third will burn repeatedly with successive exposure. Virtually all people with or without heavy skin pigmentation possess some degree of sensitivity to sunlight. It is the accumulated dosage of ultraviolet radiation over a period of years that is responsible for most wrinkling of skin on the hands and face, and the warty thickening of the skin, called solar keratoses.

Among the more serious consequences of solar exposure is the formation of skin cancer. Approximately 500,000 new cases of skin cancer were diagnosed in the United States in 1987. Presently, skin cancer represents 33 percent of the incidence of all cancer types. At this rate, one out of every seven Americans will develop some type of skin cancer in their lifetime (Mintzis, 1986). The ultraviolet light that affects skin cells is classified by three wavelengths according to its overall effect on DNA. Wavelength A (UV-A) measures between 320 and 400 nm (nanometers). It is considered to be the mildest wavelength, allowing considerably longer accumulated doses before it is carcinogenic. UV-B radiation measure between 290 and 320 nm,

and is 1600 times carcinogenic as UV-A. Wavelengths below 290 nm do not currently reach the earth's surface. The UV-B wavelength has been confirmed to be carcinogenic in animal studies, and is believed to cause a portion of human skin cancers.

Three types of skin cancer are most commonly diagnosed: (1) basal-cell, (2) squamous-cell, and (3) melanoma. The first two types of cancer together account for the most frequently detected of all cancers in humans. They are commonly termed nonmelanoma skin cancer, and are the most successfully treated cancers. Nonmelanoma skin cancer, and are the most successfully treated cancers. Nonmelanoma skin cancer, however, is a problem because of skin disfigurement, and painful and sometimes lengthy treatment. Data from the National Cancer Institute strongly support exposure to sunlight as the primary cause of nonmelanoma skin cancer. Cumulative lifetime exposure and cancer incidence is highly correlated, explaining why this condition is found predominately in the older population. Current epidemiological data have confirmed that sites of origin are on areas of the skin that are most frequently exposed to sunlight (face and lower legs in females, and the face, trunk and legs of males).

Melanoma skin cancer (malignant cancer of the pigment cells), which is treated at length in a recent paper by Pitcher (1989), can take a form of four specific types. Lentigo Maligna, Nodular, and Superficial Spreading Melanoma are common in the Caucasian population. These cancers occur either on parts of the face, neck, and hands, or on areas of the back, and legs. The fourth type, Acral Lentiginous Melanoma, predominates in Black and Orientals. For the first three types of melanoma, the differences in the tumors are related according to age at onset, clinical appearance, cellular pattern, and patient survival rate. Epidemiological studies confirm that malignant melanomas on body areas that are usually covered (like the bathing trunk areas of

males and females) are rare. Rates of malignant melanoma are increasing faster than any type of cancer in the United States, with the exception of lung cancer in women. This rate of increase has been 83 percent in the past seven years. Estimated lifetime risk of malignant melanoma for the United States is now 1 in 135 and is projected to increase to 1 in 90 by the year 2000.

Strength of evidence suggesting that sunlight is a major contributing factor in explaining skin cancer differs between melanoma and nonmelanoma cancers. On the one hand, patterns of nonmelanoma skin cancer follow a well established relation to accumulated solar ultraviolet radiation exposure. Nonmelanoma skin cancers are concentrated primarily on parts of the body most frequently exposed to the sun. Higher incidence rates are seen in groups with occupations which involve greater accumulated exposure, like farming and construction. In these specific groups, the incidence patterns change according to geographical location, yielding higher diagnosis rated in areas that receive more sunny days throughout the year.

The situation with melanoma skin cancer, however, is somewhat different. Dependence on exposure to sunlight is more difficult to document, suggesting that other contributing factors could be involved. Even though incidence and mortality rates for melanoma skin cancer follow a geographical pattern similar to nonmelanoma, the location of melanoma tumor are not as heavily concentrated on the most exposed regions of the body, as are nonmelanoma. What can be said is that the presence of melanoma is highly infrequent on the least exposed parts of the body, and that the location of tumors correspond to differences in exposure to sunlight between the sexes (i.e., more tumors are found on the legs of women, and on the chest and back of males). Incidence as a function of occupation (outdoor or indoor) does not seem to coincide as highly for melanomas as for nonmelanomas either, but changes in mortality and incidence tend to correspond with definite

patterns of exposure, which is seen in the data as a time dependent phenomenon (recent patterns of exposure have resulted in higher incidence and mortality rates).

3. VALUATION OF HEALTH EFFECTS: THE CASE OF SKIN DAMAGE

Several methods are available for estimating benefits of better health resulting from environmental improvements such as reduced rates of skin cancer that may occur if stratospheric ozone depletion can be limited. These methods focus on reductions either in mortality or morbidity. Because the overwhelming percentage of sunlight induced skin damage cases are nonfatal, methods of estimating benefits of reduced morbidity appear most relevant to consider here. (For an excellent survey focusing on estimating benefits of reduced mortality from environmental hazards, see Fisher, Chestnut, and Violette, 1986.) In particular, illness cost, contingent valuation, averting behavior methods are evaluated below. The discussion focuses on implementation procedures, results from previous studies, types of values estimated, and problems in interpretation of results, but is abbreviated in light of expanded treatment of morbidity benefit estimation methods provided by Freeman (1982) and Dickie and Gerking (1989a).

3.1 Illness Cost Method

The illness cost method adds up total out-of-pocket costs which morbidity imposes on society. Total cost is defined as the sum of medical costs (e.g. hospital, nursing and home health care, physicians services, and drugs) and the value of lost work time (See Chestnut and Violette, 1984, for a thorough discussion of the illness cost approach). Losses associated with disutility of illness, such as pain and suffering , are not included. Thus, as argued by Harrington and Portney (1987) and Berger, Blomquist, Kenkel, and Tolley (1987), the illness cost method generally

underestimates the theoretically preferable concept of willingness to pay.

The illness cost method was used to value skin cancer risks from stratospheric ozone depletion in the recently completed Regulatory Impact Assessment prepared by the U.S. Environmental Protection Agency (1988). Physiological risks first were established using dose-response functions showing how many additional U.S. cases of melanoma and nonmelanoma skin cancers would occur in people born by the year 2075 given alternative CFC and halon production scenarios. Coefficients in the dose-response relation were derived from the work of Scotto and Fears (1987). Predicted additional skin cancer cases were divided according to whether they were expected to be fatal of nonfatal. Less than two percent of predicted nonmelanoma skin cancers were classified as fatal whereas about 24 percent of melanoma skin cancers were classified as fatal. Melanoma cancers, however, represented less than one percent of skin cancers considered. Without controls on world CFC and halon production, over 177 million additional cases of skin cancer were expected to develop in people born before 2075. Further analyses indicated that the vast majority of these cases would develop in people not yet born, thus indicating the magnitude of health problems that would be left for future generations. Several other scenarios also were considered including freezing world CFC production at current levels and cutting current production by 80 percent. These scenarios reflected vastly reduced skin cancer rates; a CFC production freeze was associated with a ten fold reduction in skin cancer rates and an 80 percent production cut was associated nearly a 30 fold reduction.

Monetary benefits of reduced skin cancers were developed by a Skin Cancer Focus Group composed of specialist familiar with medical treatment costs and expected lost work time of skin cancer patients. Publicly available data on out-of-pocket costs of particular illnesses, such as

those published by Cooper and Rice (1976), do not cover types of skin cancer. The Focus Group estimated average costs of basal cell and squamous cell nonmelanoma skin cancer to be $4,000 and $7,000 per case, respectively, and placed the average cost of melanoma skin cancer at $15,000 per case. These values, together with a two percent per annum discount rate, then were used to compute monetary benefits of skin cancer avoided thorough CFC production controls. Freezing world CFC production at current levels, for example, was projected to avoid approximately 160 million skin cancers in U.S. residents born before 2075, as compared with the scenario of no controls on world CFC production, resulting in a monetary benefit of $66.5 billion for reduced morbidity. A corresponding estimated of the value of reduced mortality from skin cancer was $3,196 billion, based on applying $3 million per life saved.

These estimates, however, are subjected to several interrelated sources of error. First, and most obviously, the illness cost method does not explicitly address the major scientific uncertainties concerning relationships between CFC production, stratospheric ozone depletion and increased skin cancer risks. Second, dose-response predictions of skin cancer incidence are based on changes in solar radiation exposure alone. Additional carcinogenic factors, which may interact with solar radiation, are not considered. Third, the dose-response predictions also implicitly assume that risk reducing defensive measure such as wearing protective clothing (i.e. hats, long-sleeve shirts) or regularly applying sunscreen will not be taken. Fourth, estimates ignore disutility effects or perceptions of these effects, including fear of contracting skin cancer as well as resulting pain and disfigurement given that it occurs. As previously mentioned, therefore, the illness cost method does not estimate a theoretically correct concept of willingness to pay. Nevertheless, criticism of these illness cost estimates should not be overdrawn. As will become

apparent in the remainder of this section, no single benefit estimation method has won universal acceptance and the illness cost approach does have the advantage of requiring little or no primary data collection as well as simplicity in implementation.

3.2 Contingent Valuation

The contingent valuation method, which has been used to estimate benefits of a broad range of environmental improvements (see Cummings, Brookshire, and Schulze, 1986), generally requires collection of primary data. Survey respondents are presented with a hypothetical situation describing the increase in supply of a nonmarket good (or environmental improvement) and how payment can be made. Respondents then are asked for their maximum willingness to pay for the good described. This method has not been applied to the case of stratospheric ozone depletion and increased skin cancer risk; yet such an application would be quite natural. Neithercut, Rowe and Schulze (1987), for example, use contingent valuation to assess benefits of reduced cataracts resulting from exposure to sunlight.

An advantage of the contingent valuation method lies in its flexibility. Questions can be framed so as to capture aspects of uncertainty that are difficult to incorporate into the illness cost approach. Moreover, the good can be alternatively described so as to elicit the importance of different motives for desiring its services both at present and in the future. For example, one approach might request that respondents provide their maximum willingness to pay for some future level of skin damage protection that may by tied to preservation of stratospheric ozone. This amount of money, assuming that it can be obtained from an ideally structured survey, is interpreted as an option price comprised of two components: (1) the value of retaining an option to consume the future services of stratospheric ozone (i.e. protection from skin, eye, and immune

system damage) at some future time and (2) the expected consumer surplus that would be derived from actually consuming these services. Option price net of expected consumer surplus is referred to as option value. As discussed more fully by Fisher (1981), option value for environmental assets generally will be positive because there is value in refraining from present actions that can cause irreversible damage (such as emitting CFCs and halons into the atmosphere) and information about the extent of damage will improve with the passage of time.

The concept of option price is quite important to assessing benefits not only in the case of stratospheric ozone depletion. In particular, attention is directed to a future time which is dominated by uncertainty. Because long-term epidemiological and toxicological consequences of CFC emissions are known only imprecisely, the focus on uncertainty clearly is warranted. However, it turns out to cut in two directions, particularly when applying contingent valuation, in that perceptual uncertainties also are important. What do respondents think will happen to them if they are exposed over an extended period of time? Have they ever thought about what alternative outcomes are possible? Are they familiar with currently available scientific evidence? Do respondents believe that risks of adverse consequences of exposure can be reduced by taking defensive action or are hazards posed seen as inevitable? In any case, respondents are at least implicitly answering these and other related questions when providing option prices in a contingent valuation framework. At a minimum, therefore, contingent valuation surveys should lead respondents through a carefully structured thought process prior to eliciting values. Yet, no matter how carefully the instrument is designed, there still will be room for debate concerning interpretation of the dollar amounts obtained.

In addition to these issues, Cummings et al. (1986) review at length and Dickie and

Gerking (1989a) summarize several practical problems that can arise in applying the contingent valuation method. These problems include possibilities for strategic misrepresentation of preferences and various type of bias that may arise because of unfamiliarity with a hypothetical situation posed, the choice payment mode, or the type of bidding procedure used. Also, even in situations where these potential biases either can be avoided or minimized, contingent valuation bids obtained from survey respondents can display an uncomfortably large dispersion. Dickie, Gerking, Schulze, and McClelland (1988) cite several examples of this phenomenon from applications of contingent valuation in a health symptoms context. Mean bids sometimes were exceeded by their standard errors and individual bids often were so highly skewed that mean bids were five to ten times higher than median bids. These problems do not rule out use of contingent valuation, yet they have prompted development of alternative methods, such as the averting behavior method outlined in the next subsection.

3.3 Averting Behavior

Averting behavior models represent a second approach to estimating option prices of environmental commodities and it is the approach emphasized in this report. As discussed by Dickie and Gerking (1989b), models can be alternatively configured in order to capture key aspects of particular environmental problems. All such models are based on the principle of utility maximization and, when applied in a health context, usually incorporate household production. The particular averting behavior model used in this study is presented below.

The model to be applied closely parallels the work of Grossman (1972), Cropper (1981), Courant and Porter (1981), Gerking and Stanley (1986), and Harrington and Portney (1987). As shown in equation (1), an individual maximizes the lifetime utility (U) function

$$U = U(X, R^*, A^*, S^*) \quad (1)$$

where X denotes a composite good and remaining arguments denote perceptions about consequences of exposure to sunlight; R^* denotes perceived lifetime risk of skin cancer, A^* denotes perceived risk of premature aging or wrinkling of skin, and S^* denotes perceptions of more immediate effects of sunlight such as suntanning and/or sunburning.[1] Specifying U in lifetime terms abstracts from dynamic issues such as the timing of occurrence or recurrence of skin cancer, but conforms with how risk is measured in the data at hand (see Section 4).

Perceived consequences of sunlight exposure differ from, but are functionally related to, actual consequences:

$$\begin{aligned} R^* &= R^*(R,\alpha,\beta) \\ A^* &= A^*(A,\alpha,\beta) \\ S^* &= S^*(S,\alpha,\beta) \end{aligned} \quad (2)$$

where R denotes actual risk of skin cancer, A denotes actual risk of premature skin aging, S denotes actual suntanning/sunburning, and α and β denote attitudes toward and awareness of effects of sunlight exposure, respectively. The commodities R, A, S, in turn, are determined by

$$\begin{aligned} R &= R(T_{LS}, T_{WS}, G; \Omega) \\ A &= A(T_{LS}, T_{WS}, G; \Omega) \\ S &= S(T_{LS}, T_{WS}, G; \Omega) \end{aligned} \quad (3)$$

where T_{WS} denotes time spent in direct sunlight while at work, T_{LS} denotes time spent in sunlight at leisure, and $T = T_{WS} + T_{LS}$. Also G denotes a good that can be purchased to reduce harmful effects of sunlight, such as a sun protection product, and Ω denotes aspects of the individual's genetic endowment.[2] Choices of goods and time allocations are made subject to the full income

budget constraint

$$V = q_X X + q_G G + WT \tag{4}$$

where full income, $V = \pi W$, reflects total time available (π) valued at the individual's wage rate (W) and q_i (i = X,G) denote full, time inclusive prices (see Becker 1965 for details).[3]

This model supports three main features of the empirical analysis presented later. First, using solutions for G and $T = T_{WS} + T_{LS}$, it yields :

$$R^* = h(W, q_x, q_G, \alpha, \beta, \Omega, \pi) \tag{5}$$

which expresses skin cancer risk perceptions as the outcome of utility maximizing choices of goods and time allocations. This equation focuses on total effects of risk factors in determining risk perceptions, rather than on partial effects holding X, G, and T constant. While both types of effects are of interest, estimation of total effects is helpful to understanding the overall role of prior information, genetic susceptibility to skin cancer, and other personal characteristics in determining risk perceptions.

Second, the ex ante marginal willingness to pay or option price of a reduction in perceived risk of skin cancer can be examined by solving for the change in expenditures on G that holds utility constant as shown in equation (6)

$$d(q_G G) = (q_x U_{R^*}/U_x)dR^* + (q_x U_{A^*}/U_x)dA^* + (q_x U_{S^*}/U_x)dS^* - WdT \tag{6}$$

The desired option price is the coefficient of dR^*, the monetized marginal rate of substitution between perceived risk and the composite good. In the joint production model under consideration, however, this option price cannot be inferred from the relationship between expenditures on G and risk alone because R^* does not change independently of A^* and S^*. Hori (1975) and Bockstael and McConnell (1983) have proposed methods of estimating values of

nonmarket commodities when joint production is present; but both are difficult to implement empirically. On the one hand, Hori's approach requires knowledge of all joint production functions as well as a technological independence condition which ensures that the number of inputs available to an individual is no smaller than the number of joint products. The approach of Bockstael and McConnell, on the other hand, involves the challenge of identifying a necessary input to the joint production process.

This report develops an alternative approach to estimating option prices for nonmarket goods, which is simpler to implement when field data are collected. In the context of the model at hand, it involves: (1) defining a hypothetical sun protection product as a bundle of characteristics ($G = G(Z_R,Z_A,Z_S)$), where Z_R denotes protection against R, Z_A denotes protection against A, and Z_S denotes protection against S, and (2) varying these characteristics independently. With this refinement, the model permits independent variation in R^*, A^*, and S^* and allows the option price of a reduction in perceived skin cancer risk to be calculated as q_x times the marginal rate of substitution between R^* and X (i.e., the coefficient of dR^*). Data used to implement this approach, which center around estimation of skin cancer risk perceptions together with reservation prices for the hypothetical good, are described in Section 4.

Third, the model suggests that links between skin cancer risk and behavior can be explored empirically from four perspectives. First, after substituting for R , the household production function for R^* can be expressed as

$$R^* = f(G, T_{LS}, T_{WS}, \Omega, \alpha, \beta) \qquad (7)$$

Estimating this equation is useful in testing for possible interaction between risk beliefs and precautionary behavior and in identifying partial effects of genetic factors, information and

attitudes (Ω, α, β) on R*, holding precautionary actions (G, T_{LS}, T_{WS}) constant. Notice that if precautionary actions do not affect risk beliefs, then: (1) R* would depend only on Ω and α, and β and (2) changes in precautionary actions could not offset genetic risk factors. Second, the model can be solved for each of the three precautionary actions as functions of variables people take as exogenous. For example, G can be expressed as

$$G = g(W, q_X, q_G, \alpha, \beta, \Omega, \pi) \qquad (8)$$

Corresponding equations can be written for T_{LS} and T_{WS}. Estimates of these equations are of interest because they show how attitudes, information, genetic characteristics, and economic and demographic factors affect precautions taken. Third, recall equation (5). That equation focuses on total effects, rather than behavior-constant partial effects, of variables shown in determining beliefs about skin cancer risk. Also, because α and β appear as arguments in equation (5), total effects determined net out influences of attitudes and information concerning immediate effects of solar radiation exposure, such as suntanning.

Fourth, a measure of the extent to which behavior offsets any of the exogenous variables in determining risk beliefs can be obtained by comparing estimates of equations (5) and (7). For example, consider the case of genetic risk factors. Denote the total effect of Ω on R* from equation (7) as $dR^*/d\Omega$, denote the corresponding partial effect from equation (5) as $\partial R/\partial\Omega$, and define the difference between the two as $\Delta = dR^*/d\Omega - \partial R^*/\partial\Omega$. Assume that $\partial R^*/\partial\Omega < 0$. If precautionary behavior: (1) does not offset genetic protection, $\partial R^*/\partial\Omega = dR^*/d\Omega$ and $\Delta = 0$, (2) partially offsets genetic protection, $\partial R^*/\partial\Omega < dR^*/d\Omega$ and $\Delta > 0$, (3) exactly offsets genetic protection $dR^*/d\Omega = 0$ and $\Delta > 0$, and (4) more than offsets genetic protection, $dR^*/d\Omega > 0$ and $\Delta > 0$.

4. DATA AND SURVEY METHODOLOGY

Data on risk beliefs and related variables were collected (Appendix C contains a copy of the field data instrument) through in-person interviews with 291 individuals in Laramie, Wyoming and San Diego, California.[4] Although these communities differ substantially in average annual temperature, both have a large number of sunny days each year, and residents have experience dealing with immediate consequences of exposure to sunlight, such as suntanning and sunburning. To facilitate testing for age and gender related differences in skin cancer risk beliefs, the sampling plan for each location called for surveying 12 males and 12 females in each of six age groups (21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, and 71 years and older).[5] Thus, older cohorts were intentionally oversampled; the sample median age of 50 years exceeds that of the U.S. population by 18 years. Respondents were selected by dialing telephone numbers at random at various times during daytime and evening hours both on weekdays and weekends. After a brief introduction, in which age and gender were ascertained and the general purpose of the survey was stated, prospective respondents were added to the sample if they agreed to participate and if their age-gender cell was not already filled.[6] Prospective respondents were told that they would receive $15 at the end of a 45 minute interview and were allowed to choose a convenient time and location for the questioning.

The interview began by asking a brief sequence of questions to focus the respondent's attention on the general topic of skin damage from solar radiation exposure. For example, respondents were asked whether they ever had heard or read about skin cancer, whether they ever had been diagnosed by a physician as having this disease, and whether they knew of public figures, acquaintances, or relatives who had been treated for skin cancer. Respondents then were asked to

make an initial assessment of the risk of contracting skin cancer. Risk assessments were measured using an illustration of a ladder with steps numbered from 0 to 20.[7] Respondents were asked to choose the step that best reflected their own chance (in 20) of contracting skin cancer during the remainder of their lives (or contracting it again if they had already had it). Additionally, they were told to ignore the issue of how severe their case might be. As discussed by Slovic, Fischhoff, and Lichtenstein (1985), people more easily understand lifetime rather than annual risks of relatively low-probability events.[8]

A frequency distribution of initial risk responses (RISK0) is shown in Table 1. All steps were chosen at least three times, except the seventeenth which was never selected. The modal step chosen was the tenth. Table 1 reflects three possible and interrelated concerns with the initial risk data. First, because of the disproportionately large number of responses that occurred at steps 0, 5, 10, 15, and 20, some people appear to have been unable or unwilling to precisely estimate their risk of getting skin cancer in terms of chances in 20. Second, some respondents apparently were unsure of their answers. Immediately after providing their estimate of RISK0, respondents rated their degree of certainty in making this selection on a scale from 1 to 7 with larger values reflecting greater certainty. The mean of this variable was 4.4 with 67% of respondents choosing values of 4, 5, 6, or 7. Relatively greater uncertainty among respondents who chose lower values could arise for several reasons including a feeling of inadequate knowledge of skin cancer and/or inadequate understanding of probabilities (interviewers did explain the concept of chances in 20, however). Also, respondents who rated their degree of certainty at 1 or 2 were more likely than members of the whole sample (22% vs. 18%) to choose step 10 on the ladder; but were less likely than members of the whole sample (31% vs. 21%) to

choose steps 0, 5, 15, and 20. Interestingly, all respondents at step 20 rated their certainty level at 6 or 7 and 11 of these had a previous diagnosis of skin cancer. Further analysis indicates that degree of certainty rises with RISK0 and is lower for college graduates than for those with less schooling.

Third, people appear to have overestimated the risk of contracting skin cancer. Although Mintzis (1986) estimates that people on average have a 1 in 7 chance of contracting skin cancer during their lifetime (step 3 on the ladder), Table 1 indicates that 73% of respondents assessed their own risk at a higher level. Moreover, the mean of RISK0 (7.6) suggests that perceived risks are more than twice as high as Mintzis' estimate. This apparent overestimate is consistent with findings in related studies (for example, Viscusi 1991). However, this comparison requires further explanation for at least two reasons. First, respondents who never have had skin cancer, particularly those in the older cohorts, may now have less than a 1 in 7 chance of contracting this disease in the remainder of their lifetimes. Second, Mintzis' estimate appears to refer to the number of people who will contract skin cancer, while the initial risk question, and thus the ladder, introduces the possibility that people can contract this disease more than once. In any case, because 15% of the sample already had been diagnosed with skin cancer and because this disease frequently is recurrent, a mean of RISK0 above step 3 on the ladder would not be unexpected.

After collecting initial risk assessments, interviewers provided respondents with Mintzis' estimate for the general population by saying that "In recent studies, medical researchers have estimated that the average person has about a 3 in 20 chance of getting some type of skin cancer during his or her lifetime (Step 3 on the risk ladder)." Interviewers also explained that according

to available medical information, an individual's risk can vary from this average depending on: (1) amount of time spent in direct sunlight, (2) sensitivity of skin to sunlight, (3) extent of previous skin damage, such as severe sunburns or a prior diagnosis of skin cancer, and (4) defensive actions taken to avoid skin damage such as wearing protective clothing and using sun protection products. These risk factors were stated in order to introduce a series of questions, comprising over one half of the survey, that allowed respondents to consider their own behavior and personal characteristics affecting the chances of getting skin cancer. Quantitative effects of these factors on actual risks were not presented; in fact, available data do not permit breakdowns of skin cancer risk by trait or behavioral characteristic. Data also were collected on respondents' socioeconomic and demographic characteristics including age, gender, marital status, income, schooling, and employment. Respondents then were given an opportunity to provide a revised risk estimate (RISK1) by choosing an alternative step on the risk ladder. A frequency distribution for this variable is shown in the third column of Table 1. The mean of RISK1 is 6.8. When compared to the mean of RISK0 of 7.6, this outcome may reflect less revision in risk beliefs than occurred in related studies (Viscusi and O'Connor 1984, and Smith and Johnson 1988), a point discussed more fully later on in this report.

The final portion of the survey obtained data for valuing skin cancer risk reductions. The approach taken was to unbundle characteristics of a hypothetical sun protection product that offered protection against skin cancer for one year after use. Eight labels (see Appendix A for an example) were prepared to describe all possible combinations of three product characteristics: (1) skin cancer protection in regular strength or extra strength, (2) presence or absence of protection against premature aging of skin, and (3) sunblock formula, to prevent all burning and tanning, or

tanning formula to allow tanning but not protect against burning. Care was taken to design labels to look like those found on over-the-counter sunscreen products and to make the purchase scenario believable.[9] In particular, respondents were told (and labels also stated) that the sunscreen would be FDA approved and is guaranteed not to wash off, feel greasy, or stain clothing. Also, interviewers said that very long-lasting sunscreens may be marketed in future using results from current research on vitamin A derivative products. Two labels were randomly assigned to each respondent and of the 12 respondents in each age/gender cell in each of the two communities, six were given two extra strength labels and six were given two regular strength labels. There are six ways to form pairs of the four labels of a given strength, and each of the six pairs was given to two respondents in each cell. Thus, the labels together with the sample design allow product characteristics to vary independently and facilitate estimation of option prices for reduced skin cancer risk.

After making sure that respondents had read the first label shown, interviewers asked whether they would buy the product. Those answering "yes" (64% of the sample) then were asked: "What would be the maximum amount you would be willing to pay for the first bottle (remember that one bottle lasts an entire year)?"[10] Then all respondents, whether or not they would purchase the sunscreen, were asked to think about applying it at one year intervals for the rest of their lives, and asked whether their lifetime skin cancer risk would change if they did so. Those answering "yes" (74% of the sample) were asked to select a new step on the risk ladder to represent their lifetime risk of skin cancer assuming use of the new sunscreen. Those answering "no" were assigned their previously selected value of RISK1. This outcome resulted in the frequency distribution for RISK2 shown in the fourth column of Table 1. Finally, interviewers

gave respondents the second label in their assigned pair, allowed time to read it, and repeated the questions about purchase intentions for the first bottle and willingness to pay. The risk assessment question was not repeated because cancer protection strength was the same for each respondent.

Perceived risks conditional on lifetime use of the new sunscreen have a mean of 3.8, reflecting an average risk reduction of 2.9 ladder steps. Although 26% of respondents believed the sunscreen would not reduce their risk at all, others associated substantial risk reduction with use of the product. Expressed as a percentage of RISK1, the risk reduction has a mean of 48% and a median of 50%. Also, 18% of respondents felt that lifetime use would reduce risk to zero suggesting that possible certainty premiums in reservation prices should be investigated (see Section 6).[11]

Frequency distributions of sunscreen reservation prices, tabulated by first and second label offered, are shown in Table 2. Reservation prices range from $0, the value assigned to those who would not purchase, to $1,000; prices are disproportionately concentrated at lower values. In total, 8% of observations are above $50 per bottle and the mean price computed over both labels offered was $24.66.[12] The mean bid was 45.5% higher for the second label than for the first, although the median bid was $10 for each. Because presentation of labels was randomized, as described above, reasons why respondents tended to bid more for the second label are a matter of speculation.

5. DETERMINANTS OF RISK BELIEFS

Table 3 reports estimates of a risk perception function (equation 5) and sample means of

variables used in the analysis. Explanatory variables measure respondents' attitudes toward and awareness of skin disorders, genetic attributes, prior information, and economic circumstances that may determine risk beliefs about skin cancer and related effects of exposure to sunlight. Prices of market goods and total time available per day are assumed to be the same for all respondents and, therefore, do not appear as explanatory variables in the equations estimated. Age variables serve to proxy remaining years of life. Column 4 of Table 3 presents fully-censored regression (see Stewart 1983) estimates of an equation for RISK0. This estimation method was chosen because, as shown in Table 1, 7% of observations on RISK0 occur at the lower limit of zero and 5% occur at the upper limit of twenty. Also, this method captures the idea that respondents have a continuous, latent "true" subjective risk assessment and choose the step on the ladder that most closely reflects the value of the latent variable. Estimates presented show how respondents formed their initial risk beliefs. Data on initial risk beliefs were collected prior to obtaining information on all variables except whether respondents knew of anyone who ever had contracted skin cancer or whether they themselves ever had been diagnosed by a physician as having this disease.

The log-likelihood value for this equation suggests that initial skin cancer risk assessments are significantly related at the 1% level to measurable risk factors and related variables. Both variables measuring prior experience with skin cancer (SCDIAG and KNOWANY) positively and significantly affect RISK0. As reported by Greenberg et al. (1990), people who previously have had a nonmelanoma skin cancer face a higher risk for another. The coefficient of SCDIAG indicates that individuals previously diagnosed with skin cancer perceive lifetime risks approximately 30 percentage points higher than other individuals.

Additionally, individuals with moderately fair, medium, or dark complexions perceive lower levels of skin cancer risk as compared with those having a fair complexion. Personal experience with solar radiation exposure, such as a judgement that a lot of time previously had been spent in the sun, elevate RISK0. These results are of interest because they suggest that people account for important objective risk factors and exposure history when forming risk beliefs. Comparison of predicted RISK0 values with actual risks would be a logical next step; however, medical data on nonmelanoma skin cancers (the overwhelmingly predominant type) are weak and, as indicated previously, breakdowns by skin type and solar radiation exposure history are not possible. Thus, the issue of accuracy and rationality of perceived risk assessments is not pursued beyond testing whether beliefs are predictably related to objective risk factors.

Results also show that the youngest respondents (those in the age group 21-30) perceive significantly higher lifetime skin cancer risk than older respondents, although coefficients of dummy variables for age do not show a systematic pattern of decline. This outcome has at least two competing interpretations. First, as more fully discussed by Viscusi (1991), it is consistent with a Bayesian learning model in which younger people weight recent publicity about risk more heavily than would older people and older people weight experience with risky activities more heavily than would younger people. Further analysis, however, does not support this interpretation. Viscusi's conjecture suggests that effects of experience with solar radiation (measured by BADBURN, ALOTSUN, SCDIAG, and KNOWANY) should intensify with age. Interactions between age and experience variables, when added to the Table 3 equation for RISK0, had coefficients that were not jointly, significantly different from zero at conventional levels ($p = 0.34$).[13]

Second, the effect of age on initial risk assessments instead may suggest that respondents distinguished between marginal and cumulative hazards. As people age, they face a greater chance of experiencing skin cancer in a given year. However, members of younger cohorts appear to face larger cumulative lifetime risks, both because they would expect to live longer (and, thus, have more time available to contract skin cancer) and because lifetime skin cancer risks have been increasing. Glass and Hoover (1989) report that skin cancer risks now have grown to "epidemic proportions" and that incidence rates of squamous cell skin cancer and melanoma have increased by a factor of three or four since the 1960s. In any case, this speculation is not conclusive and the role of age or life expectancy in subjective risk assessments will be an important topic to consider in future studies.[14]

Remaining explanatory variables do not significantly affect RISK0, except that blue collar workers report higher values of RISK0 than do others.[15] This result presumably occurs because they spend more time in sunlight while on the job.[16] Men and women evidently perceive similar levels of initial risk.[17]

Column 5 of Table 3 presents fully-censored regression estimates of the determinants of RISK1, the revised estimate of lifetime skin cancer risks made by respondents after receiving information. This equation includes RISK0 as an explanatory variable, and can be interpreted in the Bayesian learning framework used by Viscusi and O'Connor (1984) and Smith and Johnson (1988). Because only 28.2% of respondents in the present study revised their original risk assessment, RISK0 is highly significant in explaining variation in RISK1, and because 88% of revisions were downward, the coefficient of RISK0 is significantly lower than unity. Remaining coefficient estimates measure effects of variables on revised risk assessments after controlling for

initial assessments.

As shown in Table 3, individuals who had a previous diagnosis and/or who knew of others having skin cancer still perceive higher risk (net of effects of RISK0) than individuals having less direct experience with the disease, while those who view avoiding skin cancer as important perceive lower risk. These results reflect the greater propensity of less knowledgeable or more concerned individuals to use information provided and then decrease their risk assessments. In an unreported probit equation to explain the probability of revision based on the same explanatory variables used in the RISK1 equation, coefficients of SCDIAG and KNOWANY are negative and significant (at 5%). The higher probability of revision among less knowledgeable individuals, coupled with the previously noted tendency to revise downward, results in the less informed group making significantly lower revised risk assessments, net of effects of initial assessments. Similarly, importance of avoiding skin cancer is positively associated with the probability of revision, leading to lower revised risk assessments among more concerned individuals.

A few other variables are significantly related to RISK1 at the five percent level in a two tail test after removing effects of RISK0. People with some sensitive skin types perceive lower levels of risk, as do males and those who recall a sunburn with blisters. The insignificant effects of age categories suggests that the effect of age on skin cancer risk beliefs operates mainly through initial assessments rather than through responses to information.

The Table 3 estimates reflect smaller revisions in risk beliefs as compared with findings of Viscusi and O'Connor (1984) and Smith and Johnson (1988). These two studies compute a ratio measuring how information received by respondents is weighted relative to information already possessed. The denominator is the weight respondents attached to their original estimate when

making their revised estimate. The numerator is the weight implicitly attached to information received, calculated using the ex post restriction that the two weights sum to unity. Ratios reported by Viscusi and O'Connor exceed unity in 7 of 8 cases considered and exceed 30 when the risk revision is largest, suggesting that information respondents received dominated prior beliefs in revised risk assessments. Smith and Johnson report a substantially smaller ratio of approximately one-third.

A similar calculation was performed by re-estimating the RISK1 equation with the constraint that the weights sum to unity, yielding a ratio of 0.16. Possible explanations for the more limited revision of risk estimates found here include: (1) when people provide their own current estimate of a risk, they may be more reluctant to alter it than in situations where they are asked to make a retrospective judgement as was necessary in the Smith and Johnson study; (2) there is a greater difference between the risk information provided and respondents' priors in the Viscusi and O'Connor study than between Mintzis' estimate and the mean of RISK0, or more generally, people may be more knowledgeable about skin cancer risk than other hazards, so that information provided by the interviewers may already have been known; (3) information provided verbally may have less impact than it would if provided in a pamphlet or label, as was done in the cited studies; and (4) the nature of the risks may differ in several important respects. Specifically, skin cancer is rarely fatal, while exposure to radon gas and certain chemicals may be associated with less easily treated diseases; many people have more direct experience with skin cancer or other consequences of sunlight exposure than they would with other diseases, as evidenced by means of SCDIAG, KNOWANY, ALOTSUN and BADBURN; and skin cancer risks are large relative to risks often considered in other studies.

6. OPTION PRICE OF REDUCING SKIN CANCER RISK

Option price estimates for reducing skin cancer risk are based on equation (6) in Section 3.3 and make use of the risk data analyzed in Section 5. In this section, attention is primarily directed to treatment of joint production and related conceptual issues. Option price estimates presented are intended to illustrate methods developed, although they also are of possible policy relevance. Results presented in Table 4 use respondents' intended expenditures (bids) on the sunscreen described in Section 4 as the dependent variable. Bids are assumed to be generated by

$$RPRICE_{ij} = \begin{cases} RPRICE_i & \text{if } RPRICE_i \geq M \\ 0 & \text{if } RPRICE_i < M \end{cases} \tag{9}$$

where $RPRICE_i$ is a latent variable measuring respondent i's (i=1,...,291) reservation price for one bottle of sunscreen on the j^{th} opportunity to purchase it (j=1,2). Positive bids are observed when $RPRICE_i$ is greater than or equal to M, the expected market price, which is assumed to be constant for all respondents. Also, as previously discussed, $RPRICE_{ij}$ pertains to a one year's supply of sunscreen, rather than to a lifetime supply as envisioned by the model. This discrepancy is treated as an errors-in-variables problem in which the always non-negative error imparts a downward bias to the estimate of the constant term, but does not affect estimates of other coefficients. Calculation of the option price hinges on the relationship between the reservation price and DRISK which measures the reduction in perceived lifetime risk of skin cancer when other sunscreen characteristics are held constant.

Estimates presented in Table 4 were obtained using maximum likelihood methods adapted from Smith and Blundell (1986). This joint estimation procedure takes account of probable

simultaneity between RPRICE and DRISK, and includes a tobit component in the likelihood function for RPRICE as well as a linear regression component for DRISK. Also, because each respondent had the opportunity to report two reservation prices, estimates are obtained in a random effects framework where the error term in the RPRICE equation is the sum of permanent and transitory components.[18] Computations used the quadrature routine of Butler and Moffitt (1982). Joint maximum likelihood estimation was pursued after application of Smith and Blundell's exogeneity test which resulted in rejecting the null hypothesis of exogeneity of DRISK at 1% significance in preliminary regressions. Estimates of the DRISK equation are reported in Appendix B. Coefficient estimates in both of the Table 4 equations are jointly, statistically significant at conventional levels. Also, estimates of the standard errors of the error components are statistically significant and indicate the relative importance of unmeasured individual effects in determining intended sunscreen expenditures.

In column (1) of Table 4, joint production is controlled by including variables measuring the contribution to value of the sunscreen arising from its perceived effects on aging and/or wrinkling of skin and suntanning/sunburning. These controls are excluded from column (2). In contrast to treatment of changes in skin cancer risk perceptions measured by DRISK, effects on aging/wrinkling and suntanning/sunburning were not directly measured in the survey. Instead, they are accounted for by including dummy variables reflecting the type of sunscreen offered (tanning, sunblock, and/or aging formulae) interacted with measures of attitudes toward the condition(s) against which protection is provided. These attitudinal effects are important because an individual's intended expenditure on sunscreen is determined jointly through interaction of product characteristics and preferences (note the presence of utility terms in equation (6)).

Comparison of the column (1) equation to the column (2) equation reveals that the controls for joint production are statistically significant at less than the 1% level using a likelihood ratio test.[19] Also, respondents who felt that avoiding sunburn was important, but who received the tanning formula label (which did not offer protection against sunburning), bid less for the new sunscreen. On the other hand, people who spend time in direct sunlight for the purpose of getting a tan bid larger amounts of money when offered a tanning formula label. In contrast to results for tanning/burning effects, labels offering protection against aging/wrinkling of skin did not inspire significantly larger reservation prices even among those who felt it important to avoid this problem. This outcome may imply that people truly are unwilling to pay for protection against aging/wrinkling of skin. It may also suggest, however, that the survey instrument did not adequately stress this factor relative to other consequences of exposure to sunlight. More generally, the contrasting results obtained for aging/wrinkling and suntanning/sunburning effects may indicate that methods adopted here to treat joint production are most effective when the consequences examined are familiar and/or immediate. Results from Table 4 can be used to compute option price estimates by income and risk category. In particular, as shown in equation (6), the coefficient of risk change (measured here as DRISK) is interpreted as the option price of a one unit reduction in risk. Because this coefficient depends on the value of time (a component of the full price of the composite good) and initial levels of risk perceived at the time the sunscreen was described, DRISK was interacted with RISK1 and a measure of income in the Table 4 regressions.[20] Estimates show that DRISK has a positive and significant effect on the sunscreen bid. This effect is significantly larger for respondents who have higher incomes and varies according to perceived skin cancer risk levels. Results of calculations are shown in Table 5 and

are interpreted as ex ante willingness to pay for a one-step movement down the risk ladder, which is equivalent to a 5 percentage point reduction in lifetime skin cancer risk. Estimates reported in Panel A of Table 5 are computed by adding the coefficient of DRISK to coefficients of relevant interaction variables from the regression in column (1) of Table 4 and incorporate controls for joint products of sunscreen use; estimates reported in Panel B are based on the column (2) regression, which does not include joint production controls.

Four features of Table 5 are worth further discussion. First, comparison of Panels A and B in Table 5 is useful because the direction and magnitude of bias resulting from omitting controls for joint production is difficult to predict a priori. Estimated option prices presented in Panel A range from $36 to $61 (1988 dollars). Omitting controls for joint products in Panel B leads to option price estimates that are as much as 25% lower than corresponding estimates in Panel A. The largest difference in option prices occur at the lowest values of RISK1 ($0 \leq RISK1 \leq 4$). Interestingly, Panel A and Panel B estimates are quite similar when $5 \leq RISK1 \leq 20$. This result may not be indicative of outcomes when joint production is analyzed in other settings; however, even comparatively small differences in option price estimates can mount into substantial sums when national benefit estimates are computed by aggregating over a population of hundreds of millions.

Second, estimates presented may provide evidence of a certainty premium in skin cancer risk valuation, thus supporting findings of Viscusi, Magat and Huber (1987). Results indicate that the option price per unit of risk reduction is significantly higher when computed from step 1 on the risk ladder, than when computed from steps 2-4. Interpreting these results as evidence of a certainty premium, however, is weakened because respondents who reported RISK1 = 1 generally

did not report RISK2 = 0, and thus did not envision making the one step change required to eliminate risk.[21] Also, the approach taken here to valuing risk reduction is not directly comparable to that used by Viscusi, Magat, and Huber, although it is consistent with the Section 3.3 model of protective behavior. In the present study, respondents may begin from any risk level and may choose any size of risk reduction; whereas in the earlier study, respondents were assigned initial risk levels and equal exogenous risk reductions.

Third, option price calculations show that: (1) risk reduction and the composite good are substitutes and (2) for RISK1 $\geq$ 2, those perceiving high initial levels of risk are willing to pay more per unit of risk reduction than those perceiving lower levels of risk.[22] The latter outcome indicates that, apart from certainty effects, the shape of indifference curves in the risk, composite good plane is consistent with theoretical analyses of Jones-Lee (1974) and Weinstein, Shepard, and Pliskin (1980) and empirical results of Jones-Lee, Hammerton, and Philips (1985) and Gerking, de Haan, and Schulze (1988) who examine traffic safety and job safety, respectively.

Fourth, option price estimates in Table 5 should be interpreted cautiously because they may be subject to sources of both upward and downward bias. On the one hand, respondents may not have fully internalized the value of risk reduction, perhaps because the sunscreen product was new to them or because they experienced difficulty in monetizing a change in risk. Also, some respondents may have implicitly made protest zero bids (recall from Table 2 that about 36% would not buy the new sunscreen) and others may have used prices of currently marketed sunscreens as a ceiling or focal point when deciding how much to bid (note that in Table 2, 116 of 362 nonzero bids for both labels were in the $1.00-$10.00 range and the median bid was $10). These concerns would result in option price estimates that are too low. On the other hand,

because estimated joint production effects of skin aging/wrinkling are quite small, another possibility is that respondents did not fully adjust their sunscreen bids to account for this effect, which might make option price estimates too large. In any case, multiplying option price estimates in Panel A of Table 5 by 20 yields values per skin cancer case avoided ranging from about $720 to about $1,200. As expected, these figures are well below commonly cited value of life estimates because skin cancer seldom is fatal. Also, they overlap at the lower end of the range of values ($1,036-$2,538) surveyed by Viscusi (1993, Table 7, pp. 1941-42) for avoiding skin poisoning from insecticide and they are below the range of medical treatment cost estimates for nonmelanoma skin cancer ($4,000-$7,000) reported by the U.S. Environmental Protection Agency (1987). Willingness to pay estimates reported here, however, envision payment to avoid a future case of skin cancer, whereas the comparative studies appear to focus on payments to avoid more immediate disorders.

7. DETERMINANTS OF PRECAUTIONARY ACTIONS

This section analyzes determinants of precautions taken to reduce skin cancer risk from solar radiation exposure (see equation (8)). Table 6 presents regression results as well as sample means and definitions of all explanatory variables used. Explanatory variables are, for the most part, the same as those used in the Table 3 regressions. Precautionary actions are measured in three ways. The binary variable LOTION indicates whether a respondent ever uses sun protection products, and LEISURE and WORK measure the leisure and work hours in a typical week spent in direct sunlight between 11:00 am and 3:00 pm, during warm weather months. Explanatory variables measure respondents' attitudes toward and awareness of possible skin

damage from sunlight, genetic attributes, and socioeconomic status. Prices of market goods and total time available per day are assumed to be the same for all sample members. The equation for sun protection product use is estimated by binomial probit and the equations for time spent outdoors are estimated by least squares. Summary statistics for each equation show that coefficients of explanatory variables are jointly significant using standard tests.

Equations for sunscreen use and outdoor hours provide evidence of offsetting behavior: People with greatest genetic protection from skin cancer tend to take fewest precautions. For example, those with medium natural skin color are less likely to use sun protection products than those with fair skin. Calculation of marginal effects based on coefficients presented in Table 6 suggests that estimated probability of sunscreen use by people with medium skin is about 37 percentage points lower than for people with fair skin when all other explanatory variables are held constant at their sample means. Coefficients of MODFAIR and DARK are negative, but are not significantly different from zero in the LOTION equation. Also, people who have medium natural skin color spend, on average, about three more leisure hours per week in direct sunlight than those with fair skin. People with medium and dark skin spend about two more work hours per week in direct sunlight than those with fair skin. Whether skin is especially sensitive to exposure to sunlight does not appear to be an important determinant of any of the three precautionary actions considered, net of effects of complexion.

Additionally, as shown in Table 6, younger, married respondents with higher household incomes, greater concerns about effects of solar radiation exposure, and who have had experience with skin cancer were more likely to have reported using sun protection products. Coefficients of these variables, however, were not different from zero at conventional levels of significance in the

LEISURE and WORK equations with the exception that older respondents appear to spend significantly less work time in direct sunlight than younger respondents. Effects of level of schooling completed appear to be weak in all three precautionary action equations estimated.[23] This result is somewhat surprising in light of prior findings by Grossman (1975), Farrell and Fuchs (1982), and Viscusi and Evans (1990), that people with more formal education are more likely to engage in health producing activities such as not smoking, wearing seatbelts, and using safety seats for young children. Finally, residents of Laramie appear to be more likely to spend leisure time outdoors during warm weather months and less likely to use sun protection products than residents of San Diego. Although merely speculation, this result may reflect differences in climate or may suggest that people in rural areas are less likely to take precautionary actions than their counterparts in urban areas.[24] Alternatively, Laramie residents may recognize that because of their more northerly latitude, precautions against solar radiation exposure are not as important. Coefficients of most other explanatory variables are not significantly different from zero.

8. DETERMINANTS OF RISK BELIEFSAND OFFSETTING BEHAVIOR

Table 7 presents estimates of equations for RISK0 and TIME and calculations of the extent of offsetting behavior. The first two columns of Table 7 estimate determinants of risk from the household production function (equation (7)) in the model presented in Section 3.3 as well as determinants of TIME (= WORK + LEISURE). Estimates reported were obtained by full information maximum likelihood. Joint estimation was pursued on efficiency grounds and to facilitate hypothesis testing (see below). The risk production function, a structural equation including TIME as an explanatory variable, is identified by excluding measures of income,

occupational status (which is associated with earning power), marital status, and attitudes toward immediate effects of sunlight exposure (compare equation (5) to equation (7) in section 3.3). The dependent variable is measured as the step on the risk ladder first chosen by each respondent and coefficients are interpreted as partial effects of a variable on RISK0, holding TIME constant. The specification shown was selected, in part, because in preliminary estimates (available from the authors on request), use of sunscreen did not affect perceived risk at conventional levels of significance and the null hypothesis that coefficients of WORK and LEISURE are identical was not rejected ($p = 0.81$). In consequence, the household production function reported in Table 7 excludes LOTION and replaces WORK and LEISURE with TIME. The equation for TIME, a reduced form, was specified identically to equations reported in Table 6. Coefficients of explanatory variables in the two equations jointly differ from zero at conventional significance levels; individual equation and systemwide χ^2 statistics exceed 1% critical values.

As expected, estimates of the TIME equation are similar to those reported in Table 6 for WORK and LEISURE and do not require further discussion. Coefficient estimates in the household production function for RISK0, interpreted as partial effects, indicate that an additional weekly hour outdoors in direct sunlight raises perceived risk by slightly more than 1 percentage point, and a prior diagnosis of skin cancer boosts perceived risk by about 30 percentage points. People who have moderately fair, medium or dark natural skin color see themselves at significantly lower risk than persons who have fair skin. Remaining coefficient estimates do not differ significantly from zero at the 10 percent level in a two-tail test, with the exception of those for the dummy variable for persons aged 70 years and older.

Implied total effects of determinants of risk beliefs, reported in Column 3 of Table 7, are

obtained by deriving the reduced form equation for RISK from estimates of the RISK production and TIME equations just discussed.[25] Total effects can be compared to partial effects from Column 2 in order to test hypotheses outlined in Section 3.3. The main hypotheses to be tested concern the extent to which behavior offsets the effect of genetic protection in the formation of risk beliefs. However, it also is of interest to consider how precautionary behavior affects relationships between risk beliefs and other variables. In consequence, differences between total effects and partial effects are computed for all exogenous variables of the model. These differences, labeled Δ_i, are shown in the fourth column of Table 7.[26] Notice that

$$\hat{\Delta}_i = \hat{\alpha}_i - \hat{\beta}_i = \hat{\gamma}\hat{\pi}_i \qquad (10)$$

where $\hat{\alpha}_i$ denotes the coefficient of a variable in the derived reduced form risk equation, $\hat{\beta}_i$ and $\hat{\pi}_i$ denote corresponding coefficients in the risk production function and reduced form TIME equation, respectively, and $\hat{\gamma}$ denotes the coefficient of TIME in the risk production function. Values of Δ_i measure the extent to which changes in behavior (i.e. time spent outdoors) offset exogenous determinants of risk beliefs in units of risk ladder steps.

Casual inspection of estimates in Table 7 suggests that effects of behavior are not strong enough to completely offset effects of genetic protection in determining risk beliefs. Coefficients of MODFAIR and MEDIUM in the reduced form RISK0 equation are negative with t-statistics exceeding 2 (in absolute value). Moreover, a Wald test of the null hypothesis that coefficients of MODFAIR, MEDIUM, DARK, and NOT TYPE 1 jointly are zero in this equation is rejected at conventional significance levels ($\chi^2(4) = 12.706$, $p = 0.0128$). Thus, results presented are not consistent with the risk homeostatis hypothesis which, as indicated in Section 3.3, predicts that $\Delta > 0$ and $dR^*/d\Omega = 0$.

The conclusion of $dR^*/d\Omega < 0$ could be reconciled with a strong lulling effect, which predicts $dR^*/d\Omega > 0$, if people with greater genetic protection underestimate the risk they actually face. Individuals who underestimate risk, however, should tend to raise their risk assessment when provided with relevant risk information. Yet results presented in this study do not support an association between greater genetic protection and upward revisions in risk beliefs. In that study, risk assessments made after receiving information were on average lower than initial risk beliefs in each complexion and skin type category. Moreover, the extent of downward revision did not appear to be smaller among those with greater genetic protection. Although people with moderately fair skin reduced their risk assessment by less than those with fair skin, people whose skin is less sensitive to sunlight (NOT TYPE 1) made greater downward revisions than those with more sensitive skin. Other complexion categories had no significant association with the extent of revision. In summary, it does not appear that people with greater genetic protection systematically underestimate the risk they face and consequently the result that $dR^*/d\Omega < 0$ is inconsistent with the lulling effect.

At the other extreme, results presented in Table 7 do not lend support for the technologists' prediction that $\Delta = dR^*/d\Omega - \partial R^*/\partial\Omega = 0$. The coefficient of TIME in the household production function for RISK0 ($\hat{\gamma}$) is equal to 0.232 with a t-statistic of 2.065. Thus, H_0: $\gamma = 0$ would be rejected in favor of H_1: $\gamma \neq 0$ at the 5% level of significance. Also, a test that coefficients of MODFAIR, MEDIUM, DARK, and NOT TYPE 1 are jointly zero in the TIME equation is rejected ($\chi^2(4) = 12.882$) at significance levels above $p = 0.0119$ and the hypothesis that γ and coefficients of these four variables are jointly zero is rejected at less than 1% ($\chi^2(5) = 16.79$, $p = 0.0049$). Therefore, because people with darker complexions appear to spend more

time outdoors, which in turn is associated with increased perceptions of skin cancer risk, behavior does appear to partially but not totally offset the beneficial effects of greater genetic protection against this disease.

These results, however, should not be over-generalized. On the one hand, values of Δ_i are not estimated precisely: a test that $\hat{\Delta}_i$ are jointly zero for MODFAIR, MEDIUM, DARK, and NOT TYPE 1 only would be rejected at significance levels exceeding p = 0.534 using a Wald statistic ($\chi^2(4) = 3.143$).[27] On the other hand, effects of behavior on actual risks faced may differ from effects on risk beliefs. If individuals overestimate small risks while underestimating large risks, then a given change in actual risk would lead to a smaller absolute change in perceived risk (Lichtenstein et al. 1978). Viscusi (1985) has shown that this pattern of risk assessments is consistent with a Bayesian learning model in which perceived risk is a weighted average of prior beliefs and the risk level implied by new information. If similar cognitive factors affect beliefs about risk changes produced by protective action, then protection will have a greater impact on actual than on perceived risk. Consequently, the actual risk effects of offsetting behavior will be absolutely larger than the perceived risk effects in Table 7.

While it is difficult to test this explanation directly, it is possible to provide some supporting evidence. Let Δ and δ measure the effect of offsetting behavior on perceived and actual risk, respectively, let $b = \partial R^*/\partial R$ from equation (2) so that $\Delta = b\delta$. If perceived risk does not fully adjust to actual risk changes, then $0 < b < 1$, and Δ will be smaller absolutely than δ. One way of testing this possibility, then, is to determine whether sample evidence is consistent with $b < 1$. Earlier in their report, it was shown that, when provided with information about relevant risk factors, respondents made very limited revisions in their skin cancer risk assessments; most of the

sample members did not change risk beliefs at all. These results suggest that risk beliefs about skin cancer are "sticky" and support a value of *b*, that is below unity. A second test rests on the observation that, if individuals differ in the responsiveness of perceived risk to actual risk changes as measured by *b*, then all else equal those with larger values of *b* should likewise have larger absolute values of Δ.[28] To perform this test, perceived risk effects of offsetting behavior were computed separately for two subsamples. The first group consists of 82 respondents whose risk beliefs changed in response to information in the previously-cited study. These individuals are assumed to have more responsive beliefs and correspondingly larger values of *b* than the second group, composed of 209 respondents whose risk beliefs did not change. Results (available from the authors on request) indicate that the measures of Δ associated with skin type and complexion are absolutely larger for the group assumed to have the larger *b* values and a likelihood ratio test for whether coefficients in the TIME and household production RISK0 equations are equal across groups is rejected at significance levels above $p = 0.0922$. Thus, both of these admittedly imperfect tests are consistent with the notion that actual risk effects of offsetting behavior may exceed the corresponding perceived risk effects.

The comparison of partial and total effects to examine the intervening role of precautionary behavior in determining risk beliefs also can be applied to other exogenous variables. The role of age is of particular interest in this context in light of Viscusi's (1991) conjecture that younger people pay more attention to recent publicity about risk than older people whereas older people weight experience with risky activities more heavily than younger people. Public warnings about skin cancer have escalated over the past 25 years; in consequence, an assessment of skin cancer risk by younger people may be expected to exceed that for older

people. The pattern of coefficients of age in the total effects RISK0 equation is broadly consistent with this view. Nevertheless, an alternative interpretation suggested earlier is that because skin cancer risks currently appear to be growing, younger people may face greater cumulative lifetime risks than older people. Thus, the total effects of age may indicate that respondents distinguished between marginal and cumulative hazards.

Table 7 presents evidence, although it is less than clear-cut, suggesting that changes in behavior may be at least partly responsible for observed alterations in risk perceptions that occur as people age. As previously indicated, γ is positive and significantly different from zero at 5%. Also, the coefficient estimates of the five age dummies in the TIME equation are all negative, but the null hypothesis that these coefficients are jointly equal to zero only can be rejected at significance levels exceeding $p = 0.18$ using the Wald test ($\chi^2(5) = 7.537$). The hypothesis that γ and the five coefficients of age are jointly zero is rejected for $p \geq 0.0316$ using a Wald test ($\chi^2(6) = 13.834$). In consequence, it appears that a portion of the difference in risk assessments between people in their twenties and those in older age groups may be attributed to differences in behavior, but the evidence on this point is weak. Nevertheless, the possibility remains that the role of age in determining risk beliefs may have a more complex, behavioral interpretation than the purely cognitive explanations suggested in earlier studies.

9. CONCLUSIONS

This report has presented empirical evidence on the formation of risk beliefs about skin cancer, links between risk beliefs and willingness to pay to reduce risk, and the extent to which precautionary actions are related to genetic risk factors. A perceived risk equation is derived

from a model in which risks are determined jointly with utility maximizing allocations of goods and time. Estimates of this equation indicate that people account for important risk factors including complexion and sunlight exposure history when assessing skin cancer risk. Perceived lifetime risks are lower among older than among younger individuals, suggesting that people are able to distinguish between marginal and cumulative hazards. The extent of revision of risk assessments in response to information is smaller than in related studies, but less knowledgeable and more concerned individuals demonstrated a greater propensity to use information provided to reduce their risk assessments. Caution should be exercised in generalizing these results to other risks, however, owing to unique features of skin cancer including the size of the risk and the amount of experience people have with skin cancer or other consequences of sunlight exposure.

The link between risk beliefs and willingness to pay to reduce risk was examined using individuals' reservation prices for a sun protection product. This product, which combined up to three types of protection from solar radiation (aging/wrinkling of skin, suntanning/sunburning, and risk of skin cancer), was described using labels. By independently varying the three types of protection across labels and obtaining reservation prices after randomly assigning labels to respondents, the value of skin cancer risk reduction could be separated from the value of other product characteristics. This approach appears to hold promise for obtaining values for other nonmarket commodities in surveys when joint production issues must be addressed. Estimates indicate that willingness to pay per unit risk reduction is positive and increases with income. Also, willingness to pay may include a certainty premium for people initially perceiving low levels of risk.

This report also has examined the concept of offsetting behavior and presented empirical

evidence on the phenomenon using measures of risk beliefs about skin cancer. In prior studies of traffic safety, the extent of offsetting behavior is indirectly measured in response to public policy changes in situations where direct measures of risk are unavailable. Results presented suggest that people with darker skin, and therefore more genetic protection against skin cancer, are less likely to use sun protection products and more likely to spend work and leisure time in direct sunlight. These behavioral differences appear to partially, but not totally, offset the beneficial effects of dark complexion in reducing skin cancer. Of course, behavioral changes may offset actual risks to a greater or lessor extent than they offset people's beliefs about risk. This outcome warrants additional research to further understanding of connections between risk and behavior in public policy settings.

ENDNOTES

1. These consequences of solar radiation exposure span the main dermatological effects discussed more fully in U.S. Environmental Protection Agency (1987). Solar radiation exposure also has been linked to immune system suppression; however, this aspect is not modeled or treated explicitly in subsequent empirical analyses. Also, perceived, rather than actual, consequences are relevant to ex ante decisions of the type examined in this paper, such as purchases of protective goods and willingness to pay to reduce risk.

2. Joint production arising because G and T are direct sources of utility is ignored in the present context but is considered at length in Dickie and Gerking (1991).

3. The budget constraint is based on simplifying assumptions that: (1) time spent to consume one unit of X and G is fixed, and (2) the individual cannot undertake more than one activity at a time. In this case, the full price equals the dollar price plus the product of the wage rate and the time required to consume one unit.

4. The survey instrument, available from the authors on request, was pretested on 21 volunteers in Laramie. Ages of these volunteers ranged from 23 to 71; nine were females. Pretesting, which led to extensive revisions in the wording and order of questions, was conducted using the same interviewers who conducted the actual survey.

5. Ideally, enough observations would be available to support separate statistical analyses (of determinants of skin cancer risk beliefs, for example) in each age/gender cell. Budget constraints, however, limited the number of respondents in the study. In consequence, the sampling plan was

aimed at collecting sufficient numbers of observations to allow for regression analysis of the entire data set with age and gender intercept shifts. Also, the sampling plan called for a total sample of 288; however, interviewers unintentionally oversampled by three. These extra observations are used in the empirical analysis.

6. Approximately 36% of prospective respondents declined to participate in the study. These individuals were disproportionately concentrated in the oldest two age groups. Comparing sample statistics with results of the 1990 census reveals that individuals who had not graduated from high school, were nonwhites or had household incomes exceeding $50,000 were underrepresented in the San Diego sample relative to their size in the population. The representation of these demographic groups in the Laramie sample, however, closely approximates their population frequencies, except that household incomes exceeding $50,000 are oversampled in Laramie while incomes less that $10,000 are undersampled.

7. Gerking, de Haan, and Schulze (1988) used a similar approach in a mail survey designed to collect risk belief information about chances of accidental death in the workplace. That paper contains a diagram of the 10-step risk ladder shown to respondents. Seven example occupations were shown beside the ladder to provide reference points. In the present study, the ladder had 20 numbered steps and was professionally drawn on a large sheet of posterboard. After the initial risk question was asked, the interviewer unfolded the posterboard to reveal the ladder, explained the concept of "chances in 20," and attempted to make sure that the respondent understood. The respondent then was handed a token (from a common board game) and asked to place it on the ladder. Respondents made subsequent risk estimates by moving the token to another step on the ladder. The

ladder did not show risks of other hazards, and there was no experimentation with other risk intervals (i.e., other than twentieths).

8. The procedure of treating risks in the context of total outcomes within a base population has been successfully applied by, for example, Viscusi (1990, 1991) and Viscusi, Magat, and Huber (1987).

9. Also, much of the terminology on the labels was chosen to resemble language found on labels of over-the-counter products, which often describe "protection" of skin and reduced "chances of skin cancer" as benefits of use. However, use of the word "protect" may have encouraged some respondents to believe that use of the sunscreen would eliminate all skin cancer risk.

10. This open-ended format for valuation questions often yields high nonresponse rates and/or a large number of protest zeros and implausibly high or low stated values (Freeman 1993, 171; Mitchell and Carson 1989). As noted by Mitchell and Carson (p. 97), however, the format works smoothly in some cases, particularly if respondents are familiar with paying for similar goods. In the present study, there is a 100% response rate to the valuation question among those who indicated they would purchase the sunscreen lotion.

11. Those who believe the sunscreen can eliminate all risk evidently attach a large (and perhaps implausible) weight to future incremental exposure relative to past exposure. Indeed, further analysis indicates that those with less past exposure perceive significantly larger risk reductions, including younger individuals and those who report they have not previously spent a lot of time outdoors in direct sunlight. In any event, neither the product labels nor the interviewers offered

specific instructions on distinguishing past from future exposure.

12. A possible concern about the sunscreen reservation price data relate to the $15 payment to respondents for participating in the survey. However, because all respondents received the payment, this potential source of bias cannot be investigated.

13. Results from this and other supplementary regressions referred to later in the text are available from the authors on request.

14. It may be hypothsized that effects of solar radiation experience may not intensify with age because tanning was not a way to show a healthy and attractive appearance until relatively recently. Earlier in life, older people may have avoided the sun to maintain a youthful look and to avoid leaving the impression that they had to work outdoors.

15. The "importance" variables (IMPSKCAN, IMPAGING, IMPBURN) are included as measures of attitudes towards effects of sunlight exposure (denoted as α in equation (5)). These variables are jointly insignificant in the RISK0 equation, however, and removing them does not substantially alter other coefficients.

16. A supplementary regression (available on request) to explain time currently spent outdoors between 10:00 a.m. and 3:00 p.m. suggests that blue collar workers spend significantly more work time but no more leisure time in direct sunlight than other individuals. Also, current exposure is not as closely related to historical exposure as might be expected; the Pearson correlation between BLUE and ALOTSUN is 0.11.

17. Men and women appear to weight the various determinants of risk differently, however. When the RISK0 equation is re-estimated including interactions between all explanatory variables and MALE, the hypothesis that coefficients of interaction variables are jointly zero is rejected at less than 1%.

18. A three step procedure was used to obtain the estimates presented. First, a least squares regression of RPRICE on its determinants was estimated with no account taken of repeated observations to obtain initial coefficient values. Second, these initial values were used in joint maximum likelihood estimation of RPRICE and DRISK equations with no account taken of repeated observations. Third, joint maximum likelihood estimates incorporating the variance components structure were obtained using the step two estimates as start-up values. Note that the variance components framework incorporated here was not treated by Smith and Blundell (1986).

19. Twice the difference in likelihood values in the Table 4 equations is χ^2 distributed with 10 degrees of freedom. (When the five joint production controls were excluded in estimating the column (2) equation, they also were excluded from the corresponding equation for DRISK.) The value of this statistic is 64.40 whereas the 1% significance point is 23.209.

20. Respondents are expected to interpret benefits of the product in light of their own estimates of initial risk and risk change. Regressors involving DRISK and initial risk levels control for variation in these perceptions.

21. An alternative approach which avoids this problem (but introduces others) is to allow marginal valuation to differ for those who report zero final risk (RISK 2 = 0), regardless of their initial

risk level. This approach was implemented by replacing the baseline risk (RISK1) categories in Table 4 with final risk categories (RISK2). Results indicate that the marginal value of risk reduction is significantly greater when final risk is zero than when final risk falls on steps 1 or 2 of the ladder. Marginal values then increase with further increases in final risk. These results offer additional support for existence of certainty premia but should be interpreted cautiously because: (1) RISK2 was treated as exogenous while for consistency with the model and exogeneity tests of Table 4, RISK2 should be viewed as endogenous, and (2) the approach does not distinguish between those who move to RISK2 = 0 with use of the new sunscreen and those who already perceived RISK1 = 0.

22. Although the option price of risk reduction at the highest initial risk levels ($15 \leq RISK1 \leq 20$) is smaller than the coefficient of R4 is lower at the next highest risk level ($10 \leq RISK \leq 14$), this difference is not significantly different from zero at five percent.

23. In a preliminary specification, equations for LOTION, WORK, and LEISURE were estimated using four schooling categories (all defined as highest attainment): (1) less than high school graduation (excluded category), (2) high school graduation, (3) college graduation, and (4) advanced degree. In the WORK and LEISURE equations, the null hypothesis that coefficients of the three dummy variables are jointly equal to zero is not rejected at conventional significance levels. In the LOTION equation, the corresponding hypothesis is rejected at the 5% level. In that equation, however, the coefficient of the college graduation dummy was significant at 10% using a two-tail test and coefficients of the other two schooling dummies were not significant at conventional levels. In light of these outcomes, only COLGRAD is used in the final specification reported in Table 2.

24. This result is similar to estimates of Evans and Graham (1990) who found that the car-occupant fatality rate for children under five years old was greater in states where a greater percentage of vehicle miles are traveled in rural areas.

25. These derived reduced form coefficients were obtained by substituting the estimated TIME equation in Column 1 into the RISK0 equation in Column 2. Additionally, direct single-equation estimates of the reduced form risk production function by fully censored regression previously were reported in Table 3. Although the two sets of reduced form risk estimates are closely related, the derived estimates are more appropriate for the purposes at hand because they take account of the over-identifying restrictions on the household production function for risk, whereas the direct estimates do not.

26. Standard errors for the estimates of Δ_i were found using the same approach as was applied to find standard errors for the derived reduced form coefficients.

27. Intuitively, the Δ_i are estimated imprecisely relative to γ or corresponding π_i coefficients because computing $\hat{\Delta}_i$ compounds uncertainty from estimation of both γ and π_i. To illustrate, note that since $\hat{\Delta}_i = \hat{\gamma}\hat{\pi}_i$, estimated t-ratios for $\hat{\Delta}_i$ and $\hat{\pi}_i$ would be identical if var($\hat{\Delta}_i$) were equal to $\hat{\gamma}^2$ var($\hat{\Delta}_i$). But the approximate var($\hat{\Delta}_i$) is estimated by

$$\hat{\gamma}^2 \text{var}(\hat{\pi}_i) + \hat{\pi}_i^2 \text{ var}(\hat{\gamma}) + 2\hat{\gamma}\hat{\pi}_i \text{cov}(\hat{\gamma}, \hat{\pi}_i).$$

Barring the unlikely occurrence that the covariance term is both (a) large absolutely relative to the variances and (b) opposite in sign to the product $\hat{\gamma}\hat{\pi}_i$, var($\hat{\Delta}_i$) will exceed both $\hat{\gamma}^2$var($\hat{\pi}_i$) and $\hat{\pi}_i^2$ var($\hat{\gamma}$). Then, $\hat{\Delta}_i$ will have a smaller t-ratio than either $\hat{\gamma}$ or $\hat{\pi}_i$. In the present case the covariances tend to be an order of magnitude smaller than the variances, making a large difference

in significance levels for tests of Δ compared to tests of γ or π. (For example, the standard error for the Δ coefficient of MEDIUM can be computed using the formula above and information in Table 6 together with the relevant covariance -0.00088.) The practical implication is that larger samples are required to estimate Δ than to estimate γ or π at conventional significance levels, a point that may be useful in designing future research.

28. This is an imperfect test because it is likely that optimizing individuals would change their behavior in response to changes in *b*, complicating comparisons between actual and perceived risk effects. Specifically, an increase in *b* with the overall level of perceived risk held constant raises the perceived risk effect of protective action, and thus leads the individual to increase protection. However, an increase in *b* also raises the perceived risk effect of genetic protection, which may lead to reduced protective action, leaving the total effect of the change in *b* ambiguous.

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TABLE 1
FREQUENCY DISTRIBUTION OF RISK RESPONSES

Step	Number of Responses Initial (RISK0)	Revised Final (RISK1)	(RISK2)
0	21	19	71
1	22	19	45
2	20	29	34
3	17	38	35
4	12	23	17
5	39	25	23
6	9	15	15
7	18	14	8
8	15	12	5
9	3	4	2
10	51	42	10
11	3	3	3
12	8	5	1
13	3	4	1
14	5	1	2
15	17	14	6
16	4	4	4
17	0	1	1
18	5	2	1
19	4	3	2
20	15	14	5
Total Responses	291	291	291
Mean Step Chosen	7.6	6.8	3.8

TABLE 2
FREQUENCY DISTRIBUTION OF SUNSCREEN
RESERVATION PRICES BY LABELS

Reservation Price	Number of Responses		
	First Label	Second Label	Total
$0 (Would not purchase)	107	103	210
$ 1.00 - $ 5.00	22	22	44
$ 5.01 - $ 10.00	43	29	72
$ 10.01 - $ 15.00	18	25	43
$ 15.01 - $ 20.00	31	26	57
$ 20.01 - $ 25.00	20	22	42
$ 25.01 - $ 50.00	31	36	67
$ 50.01 - $ 75.00	2	9	11
$ 75.01 - $100.00	10	10	20
$100.01 - $200.00	5	4	9
$200.01 - $300.00	1	0	1
$300.01 - $500.00	1	4	5
$1000	0	1	1
Total Responses	291	291	582
Median Reservation Price	$10	$10	$10
Mean Reservation Price (including $0 amounts)	$20.12	$29.29	$24.66

TABLE 3
DETERMINANTS OF RISK0 AND RISK1

Explanatory Variable	Definition	Sample Mean	Dependent Variables[a]	
			RISK0	RISK1
RISK0	= Initial lifetime skin cancer risk assessment	---	---	0.920* (0.03)
SCDIAG	= 1 if have been diagnosed with skin cancer	0.15	6.295* (1.00)	1.503* (0.42)
KNOWANY	= 1 if know acquaintance or relative or know of a public figure who has had skin cancer	0.87	1.806* (0.94)	0.942* (0.38)
FAIR	= 1 if natural skin color is fair	0.20	---[b]	---[b]
MODFAIR	= 1 if natural skin color without suntan is moderately fair	0.39	-2.545* (0.88)	0.132* (0.35)
MEDIUM	= 1 if natural skin color without suntan is medium	0.29	-2.903* (0.96)	-0.109 (0.39)
DARK	= 1 if natural skin color without suntan is dark/olive	0.12	-2.119* (1.19)	-0.121 (0.48)
NOT TYPE1	= 1 if skin response to 2 hrs direct sunlight without special protection is not "always burns"	0.62	-0.496 (0.72)	-0.694* (0.29)
BADBURN	= 1 if have ever had a sunburn with blisters	0.56	1.106 (0.66)	-0.629* (0.27)
ALOTSUN	= 1 if have spent a lot of time in sun in lifetime	0.77	2.038* (0.76)	-0.027 (0.31)
TWENTY	= 1 if age 21-30	0.16	---[b]	---[b]
THIRTY	= 1 if age 31-40	0.17	-2.135* (1.07)	-0.205 (0.43)
FORTY	= 1 if age 41-50	0.17	-1.107 (1.15)	-0.064 (0.46)
FIFTY	= 1 if age 51-60	0.17	-3.119* (1.18)	-0.342 (0.48)
SIXTY	= 1 if age 61-70	0.16	-2.448* (1.26)	-0.325 (0.50)
SEVENTY	= 1 if age 71 or older	0.17	-3.102* (1.29)	-0.776 (0.52)
MALE	= 1 if male	0.50	-0.415 (0.66)	0.723* (0.26)
IMPSKCAN	= 1 if avoiding skin cancer not unimportant	0.71	0.074 (0.95)	-0.806* (0.38)
IMPAGING	= 1 if avoiding premature aging of skin not unimportant	0.73	0.663 (0.86)	0.083 (0.34)
IMPBURN	= 1 if avoiding sunburn not unimportant	0.73	0.694 (0.86)	0.542 (0.35)

TABLE 3
DETERMINANTS OF RISK0 AND RISK1

Explanatory Variable	Definition	Sample Mean	Dependent Variables[a]	
			RISK0	RISK1
LARAMIE	= 1 if live in Laramie, 0 if San Diego	0.50	-0.107 (0.65)	-0.526* (0.26)
MARRIED	= 1 if currently married	0.56	1.082 (0.71)	0.177 (0.28)
INCOME	household annual income, ten thousand dollars	3.39	0.091 (0.19)	-0.101 (0.08)
COLLGRAD	= 1 if college graduate	0.39	0.552 (0.69)	0.070 (0.28)
EMPLOYED	= 1 if employed full- or part-time	0.55	0.735 (0.81)	-0.279 (0.32)
BLUE	= 1 if blue-collar occupation	0.25	1.556* (0.77)	0.131 (0.31)
CONSTANT		---	4.752* (1.77)	-0.756 (0.72)
σ		---	5.081* (0.23)	1.993* (0.09)
Log-Likelihood			-811.82	-568.19
Chi-Sq			103.90	589.72
p-value for likelihood ratio test that coefficients of all explanatory variables are jointly zero			<.001	<.001

[a]Asymptotic standard errors in parentheses beneath coefficient estimates.
[b]Denotes omitted dummy variable.
*Denotes significance at 5% level using 1 tail test.

TABLE 4
DETERMINANTS OF THE SUNSCREEN RESERVATION PRICE[a]

Explanatory Variable	Definition	Sample Mean	Coefficient Estimates[b] (1)	(2)
DRISK	= -(RISK2-RISK1)	2.93	54.703* (7.73)	43.718* (6.87)
R1	= 0 ≤ RISK1 ≤ 1	0.13	---[c]	---[c]
R2	= 2 ≤ RISK1 ≤ 4	0.31	45.028* (7.92)	27.880* (9.17)
R3	= 5 ≤ RISK1 ≤ 9	0.24	-29.325* (10.99)	-60.248* (12.83)
R4	= 10 ≤ RISK1 ≤ 14	0.19	-69.641* (15.90)	-95.562* (15.65)
R5	= 15 ≤ RISK1 ≤ 20	0.13	-147.72* (21.77)	-157.61* (22.98)
LOWINC	= 1 if household annual income <$20,000	0.30	---[c]	---[c]
MEDINC	= 1 if $20,000 ≤ household annual income <$40,000	0.38	-15.532 (24.03)	-9.012 (22.88)
HIGHINC	= 1 if household annual income ≥ $40,000	0.32	-0.683 (26.32)	-4.971 (23.85)
R2*DRISK	= Interaction of R2 and DRISK	0.74	-17.905* (4.85)	-4.117 (4.92)
R3*DRISK	= Interaction of R3 and DRISK	0.98	-4.383 (4.08)	6.966 (4.35)
R4*DRISK	= Interaction of R4 and DRISK	0.63	-2.833 (4.07)	9.296* (3.97)
R5*DRISK	= Interaction of R5 and DRISK		-4.883 (3.87)	6.532 (4.08)
MED*DRISK	= Interaction of MEDINC and DRISK	1.17	0.675 (1.43)	-1.972 (1.45)
HIGH*DRISK	= Interaction of HIGHINC and DRISK	0.95	6.045* (1.47)	5.938* (1.65)
DT	= 1 if respondent uses sun protection products to remain in sunlight for a longer time	0.34	-14.744 (21.95)	-13.343 (20.11)
AGEFRM	= 1 if label indicated protection against aging	0.50	2.922 (4.59)	---[c]
TANFRM	= 1 if label indicated no protection against sunburn	0.50	6.361 (5.86)	---[c]
IMPAGING* AGEFRM	= Interaction of IMPAGING and AGEFRM	0.23	9.400 (7.52)	---[c]
IMPBURN* TANFRM	= Interaction of IMPBURN and TANFRM	0.33	-11.430* (7.02)	---[c]

TABLE 4
DETERMINANTS OF THE SUNSCREEN RESERVATION PRICE[a]

Explanatory Variable	Definition	Sample Mean	Coefficient Estimates[b]	
			(1)	(2)
TANTRY* TANFRM	= Interaction of TANTRY[d] and TANFRM	0.11	19.118* (8.53)	---[c]
CONSTANT		----	-112.59* (32.02)	-92.540* (29.65)
σ_v	Standard deviation of transitory error component	----	24.874* (0.81)	24.865* (0.71)
σ_u	Standard deviation of individual specific error component	----	38.654* (1.80)	37.979* (1.98)
Log-Likelihood			-2822.3	-2854.5

[a]The reservation price equation is estimated jointly with the DRISK equation.
[b]Asymptotic standard errors in parentheses beneath coefficient estimates.
[c]Excluded variable.
[d]TANTRY = 1 if respondent reports spending time in sunlight mainly for the purpose of getting a tan.
*Denotes significance at 5% level using 1 tail test.

TABLE 5
OPTION PRICES TO REDUCE SKIN CANCER RISK[a]

Risk Category	Low Income	Medium Income	High Income
A.WITH JOINT PRODUCTS[b]			
$0 \leq RISK1 \leq 1$	\$54.70	\$55.38	\$60.75
	(7.734)	(7.597)	(7.416)
$2 \leq RISK1 \leq 4$	\$36.80	\$37.47	\$42.84
	(7.873)	(7.647)	(7.493)
$5 \leq RISK1 \leq 9$	\$50.32	\$51.00	\$56.37
	(7.561)	(7.385)	(7.184)
$10 \leq RISK1 \leq 14$	\$51.87	\$52.55	\$57.92
	(7.250)	(7.087)	(6.921)
$15 \leq RISK1 \leq 20$	\$49.82	\$50.50	\$55.87
	(7.544)	(7.259)	(7.067)
B.WITHOUT JOINT PRODUCTS[b]			
$0 \leq RISK1 \leq 1$	\$43.72	\$41.75	\$49.66
	(6.865)	(6.940)	(6.631)
$2 \leq RISK1 \leq 4$	\$39.60	\$37.63	\$45.54
	(7.661)	(7.747)	(7.255)
$5 \leq RISK1 \leq 9$	\$50.68	\$48.71	\$56.62
	(7.273)	(7.372)	(6.898)
$10 \leq RISK1 \leq 14$	\$53.01	\$51.04	\$58.95
	(6.887)	(7.01)	(6.613)
$15 \leq RISK1 \leq 20$	\$50.25	\$48.28	\$56.19
	(7.409)	(7.50)	(6.899)

[a]Ex ante willingness to pay (1988 dollars) per one ladder step (5 percentage point) reduction in lifetime risk of contracting skin cancer. Computed based on equation (6) and results in Table 4.
[b]Asymptotic standard errors in parentheses.

TABLE 6
DETERMINANTS OF
TIME OUTDOORS AND SUNSCREEN USE [a]

EXPLANATORY VARIABLE	DEFINITION	SAMPLE MEAN	DEPENDENT VARIABLE		
			LOTION	LEISURE	WORK
CONSTANT			-1.069 (-1.264)	1.617 (0.625)	2.737 (1.385)
SCDIAG	= 1 if have been diagnosed with skin cancer	0.15	1.290 (2.773)	-1.319 (-0.910)	-0.320 (-0.289)
BADBURN	= 1 if ever have had a sunburn with blisters	0.56	-0.169 (-0.567)	0.784 (0.780)	.0843 (1.098)
ALOTSUN	= 1 if have spent a lot of time in sun during lifetime	0.77	0.140 (0.407)	1.111 (0.951)	1.599 (1.792)
KNOWANY	= 1 if know of acquaintance, relative, or public figure who has had skin cancer	0.87	0.366 (0.862)	0.970 (0.672)	1.295 (1.175)
FAIR	= 1 if natural skin color is fair	0.21	- - - [b]	- - - [b]	- - - [b]
MODFAIR	= 1 if natural skin color is moderately fair	0.38	-0.732 (-1.559)	0.202 (0.152)	0.330 (0.326)
MEDIUM	= 1 if natural skin color is medium	0.29	-1.166 (-2.471)	2.993 (2.056)	1.888 (1.698)
DARK	= 1 if natural skin color is dark	0.12	-0.630 (-1.170)	1.939 (1.069)	2.298 (1.659)
NOTTYPE1	= 1 if skin's response to 2 hrs. in direct sunlight without special protection is not always burn	0.62	0.080 (0.243)	-0.530 (-0.485)	-1.167 (-1.397)

EXPLANATORY VARIABLE	DEFINITION	SAMPLE MEAN	DEPENDENT VARIABLE		
			LOTION	LEISURE	WORK
TWENTY	= 1 if age 21-30	0.17	- - - [b]	- - - [b]	- - - [b]
THIRTY	= 1 if age 31-40	0.17	-1.093 (-1.673)	-0.554 -0.332)	-0.517 (-0.406)
FORTY	= 1 if age 41-50	0.17	-1.350 (-2.135)	-1.869 (-1.069)	-3.856 (-2.889)
FIFTY	= 1 if age 51-60	0.16	-2.665 (-3.665)	-0.439 (-0.242)	-2.542 (-1.837)
SIXTY	= 1 if age 61-70	0.16	-2.308 (-3.505)	0.390 (0.218)	-6.049 (-4.434)
SEVENTY	= 1 if age 71 or older	0.16	-2.803 (-4.529)	0.956 (0.533)	-5.539 (-4.040)
MALE	= 1 if male	0.50	-0.007 (-0.025)	0.088 (0.092)	1.445 (1.964)
LARAMIE	= 1 if live in Laramie; = 0 if live in San Diego	0.50	-0.471 (-1.674)	4.330 (4.380)	-0.332 (-0.440)
COLGRAD	= 1 if college graduate or advanced degree	0.39	0.473 (1.528)	-0.116 (-0.111)	1.018 (1.268)
BLUE	= 1 if blue collar occupation	0.25	-0.427 (-1.199)	0.121 (0.104)	1.820 (2.049)
LOWINC	= 1 if household income < $25,000 per year	0.30	- - - [b]	- - - [b]	- - - [b]
MEDINC	= 1 if household income > $25,0 but < $45,000 per year	0.38	0.462 (1.264)	-0.967 (-0.748)	0.309 (0.312)

EXPLANATORY VARIABLE	DEFINITION	SAMPLE MEAN	DEPENDENT VARIABLE		
			LOTION	LEISURE	WORK

HIGHINC	= 1 if household income > $45,000 per year	0.32	0.695 (1.682)	0.109 (0.075)	0.653 (0.589)
MARRIED	= 1 if married	0.56	0.570 (1.795)	-0.430 (-0.400)	1.000 (1.219)
AVOID CANCER	= 1 if avoiding skin cancer not unimportant	0.71	0.955 (1.857)	-0.208 (-0.093)	-1.755 (-1.032)
IMPBURN	= 1 if avoiding sunburn not unimportant	0.73	2.805 (5.061)	-0.117 (-0.051)	0.120 (0.068)
TAN	= 1 if think look healthier or more attractive with suntan	0.59	0.395 (1.418)	2.705 (2.626)	0.299 (0.380)

SUMMARY STATISTICS

Mean of Dependent Variable	0.64	7.10	4.00
Number of Observations	291	291	291
R^2	---	0.141	0.216
F(23, 267)	---	1.90	3.20
Log-Likelihood	-62.18	---	---
$\chi^2(23)$	257.33	---	---
Estimation method	Probit	OLS	OLS

[a] t-statistics shown in parenthesis beneath coefficients
[b] denotes omitted dummy variable

TABLE 7
DETERMINANTS OF RISK, TIME, AND Δ [a]

EXPLANATORY VARIABLE	MAXIMUM LIKELIHOOD ESTIMATES		IMPLIED TOTAL EFFECTS	$\hat{\Delta}_i$
	TIME	RISK	RISK	
CONSTANT	-0.582 (-0.148)	5.702 (2.910)	5.567 (2.792)	-0.135 (-0.149)
SCDIAG	-2.439 (-1.111)	6.235 (6.395)	5.668 (5.868)	-0.567 (-1.016)
BADBURN	1.590 (1.185)	0.786 (1.131)	1.156 (1.878)	0.369 (0.987)
ALOTSUN	2.850 (1.694)	1.146 (1.375)	1.808 (2.435)	0.662 (1.275)
KNOWANY	2.515 (1.211)	1.267 (1.002)	1.851 (1.619)	0.584 (1.067)
FAIR	---[b]	---[b]	---[b]	---[b]
MODFAIR	0.314 (0.177)	-2.108 (-2.331)	-2.035 (-2.418)	0.073 (0.177)
MEDIUM	4.984 (2.938)	-3.609 (-2.841)	-2.450 (-2.265)	1.159 (1.693)
DARK	3.787 (1.517)	-2.627 (-2.047)	-1.746 (-1.490)	0.880 (1.236)
NOTTYPE1	-1.336 (-0.934)	-0.359 (-0.464)	-0.670 (-0.925)	-0.311 (-0.860)
TWENTY	---[b]	---[b]	---[b]	---[b]
THIRTY	-1.896 (-0.909)	-1.456 (-1.164)	-1.896 (-1.594)	-0.441 (-0.827)
FORTY	-5.856 (-2.480)	0.297 (0.228)	-1.064 (-1.069)	-1.361 (-1.671)

EXPLANATORY VARIABLE	MAXIMUM LIKELIHOOD ESTIMATES		IMPLIED TOTAL EFFECTS	$\hat{\Delta}_i$
	TIME	RISK	RISK	
FIFTY	-2.038 (-0.785)	-1.772 (-1.307)	-2.246 (-1.884)	-0.474 (-0.709)
SIXTY	-2.084 (-0.792)	-1.262 (-0.839)	-1.746 (-1.310)	-0.484 (-0.724)
SEVENTY	-0.538 (-0.197)	-2.622 (-1.855)	-2.747 (-1.967)	-0.125 (-0.195)
MALE	1.102 (0.842)	-0.848 (-1.149)	-0.591 (-0.904)	0.256 (0.782)
LARAMIE	4.281 (3.241)	-0.973 (-1.068)	0.022 (0.033)	0.995 (1.725)
COLGRAD	0.679 (0.502)	0.113 (0.167)	0.271 (0.411)	0.158 (0.480)
BLUE	2.202 (1.600)	----[b]	0.334 (0.400)	---[c]
LOWINC	---[b]	---[b]	---[b]	---[b]
MIDINC	-0.234 (-0.138)	---[b]	0.512 (1.303)	---[c]
HIGHINC	1.057 (0.635)	---[b]	-0.054 (-0.138)	---[c]
AVOID CANCER	-0.401 (-0.148)	0.427 (0.546)	0.246 (0.614)	-0.093 (-0.148)
IMPBURN	-1.535 (-0.593)	---[b]	-0.357 (-0.565)	---[c]
MARRIED	1.113 (0.770)	----b-	0.259 (0.737)	---[c]

EXPLANATORY VARIABLE	MAXIMUM LIKELIHOOD ESTIMATES		IMPLIED TOTAL EFFECTS	$\hat{\Delta}_i$
	TIME	RISK	RISK	
TAN	2.656 (2.174)	---[b]	0.617 (1.601)	---[c]
TIME	---[b]	0.232 (2.065)	---[b]	---[c]

SUMMARY STATISTICS

NUMBER OF OBSERVATIONS	291	291	291
$\chi^2(23)$	55.092	---	93.755
$\chi^2(18)$	---	87.941	---
$\chi^2(41)$	181.059		

[a]t-statistics shown in parentheses beneath coefficient estimate
[b]denotes omitted variable
[c]denotes calculation not applicable

APPENDIX A
EXAMPLE SUNSCREEN LABEL

(FRONT OF BOTTLE)

SKINSAVER®

Sun Protection Lotion

"The skin protection with staying power."
Lasts up to one full year.

REGULAR STRENGTH | TANNING FORMULA

UVB PROTECTION

(UVB's are the harmful ultraviolet rays)

4 fluid ounces

(BACK OF BOTTLE)

New SKINSAVER® sun protection lotion is dermatologist-tested to protect your skin from the harmful effects of the sun.

* REGULAR STRENGTH helps protect your skin from the chance of getting skin cancer.
* TANNING FORMULA allows your skin to tan as it would naturally, does not protect against burning.
* UVB PROTECTION blocks UVB light, helping protect against wrinkling and premature aging of your skin.
* One application lasts up to one full year.
* FDA approved.
* Hypoallergenic.
* Unscented.

DIRECTIONS: For the most complete protection, apply entire contents of bottle to all areas of your skin not covered by a bikini swimsuit. Allow 15 minutes before bathing, swimming, or heavy exertion. FOR EXTERNAL USE ONLY.

ACTIVE INGREDIENTS: Octyl Methoxycinnamate, Benzophene-3, titanium dioxide.

APPENDIX B

DETERMINANTS OF DRISK*

Explanatory Variable	Coefficient Estimates (1)	(2)
RISK1	0.213[a]	0.204[a]
	(0.027)	(0.024)
KNOWANY	-0.037	0.079
	(0.123)	(0.126)
FAIR	---[b]	---[b]
MODFAIR	-0.025	0.047
	(0.087)	(0.084)
MEDIUM	0.150	-0.023
	(0.098)	(0.102)
DARK	0.244[a]	-0.042
	(0.119)	(0.131)
NOTTYPE1	0.015	0.042
	(0.084)	(0.085)
BADBURN	0.433[a]	0.162[a]
	(0.096)	(0.077)
ALOTSUN	-0.074	0.020
	(0.081)	(0.083)
EMPLOYED	0.169[a]	0.091
	(0.102)	(0.104)
BLUE	0.052	-0.038
	(0.084)	(0.085)
SCDIAG	0.239[a]	0.875[a]
	(0.113)	(0.162)
TWENTY	---[b]	---[b]
THIRTY	-0.753[a]	-0.784[a]
	(0.155)	(0.177)

APPENDIX B -- Continued

DETERMINANTS OF DRISK*

Explanatory Variable	Coefficient Estimates (1)	(2)
FORTY	-0.993[a]	-1.226[a]
	(0.194)	(0.212)
FIFTY	-0.761[a]	-1.090[a]
	(0.169)	(0.218)
SIXTY	-0.839[a]	-0.904[a]
	(0.193)	(0.218)
SEVENTY	-0.956[a]	-1.069[a]
	(0.212)	(0.227)
HSGRAD	-0.294	-0.288[a]
	(0.179)	(0.166)
COLLGRAD	0.248	0.276
	(0.185)	(0.176)
ADVGRAD	-0.167	-0.160
	(0.203)	(0.192)
LARAMIE	-0.316[a]	-0.069
	(0.084)	(0.075)
MALE	-0.342[a]	0.184[a]
	(0.091)	(0.073)
IMPSKCAN	0.500[a]	0.070
	(0.167)	(0.120)
IMPAGING	-0.428[a]	-0.153[a]
	(0.136)	(0.093)
IMPBURN	0.426[a]	0.419[a]
	(0.153)	(0.119)
NOTTRY	0.906[a]	0.069
	(0.184)	(0.100)
LOWINC	---[b]	---[b]

APPENDIX B -- Continued

DETERMINANTS OF DRISK*

Explanatory Variable	Coefficient Estimates (1)	(2)
MEDINC	0.323 (0.486)	0.418 (0.473)
HIGHINC	-0.076 (0.515)	-0.022 (0.493)
DT	0.038 (0.436)	0.123 (0.422)
AGEFRM	-0.528[a] (0.129)	---[b]
TANFRM	-0.164 (0.142)	---[b]
IMPAGING* AGEFRM	0.656[a] (0.183)	---[b]
IMPBURN* TANFRM	-0.630[a] (0.182)	---[b]
TANTRY* TANFRM	0.538[a] (0.214)	---[b]
CONSTANT	1.390[a] (0.571)	1.567[a] (0.570)
σ^c	2.537[a] (0.083)	2.540[a] (0.092)
$(\sigma_{12}/\sigma^2)^d$	-49.622[a] (7.062)	-47.569[a] (6.834)

*For variable means and definitions, see Tables 3 and 4. Estimated standard errors in parentheses.
[a]Denotes significance at 5% using one-tail test.
[b]Denotes omitted variable.
[c]Standard deviation of residual.
[d]Cross-equation error correlation (between DRISK residual and transitory error component) divided by RISK residual variance.